Automated Vehicles:
What, Why & When

by

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Princeton University

Presented at

NYSAMPO 2017 Annual Conference
June 21, 2017
Syracuse, NY

SmartDrivingCars
Why, What, When
& Implications on MPOs

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Outline

- Why:
  - **Problem statement**
    - Safety, Personal Pleasure & Mobility (Quality-of-Life)
- What & When:
  - Levels of "**Smart**ness"
    - **'Safe-driving Car', 'Self-driving Cars' & 'Driverless Cars'**
- Implications & How can MPOs help:
  - **the 'Good', the 'Bad' & the 'Great**

- Why:
  - **Problem statement**
    - Safety, Personal Pleasure & Mobility (Quality-of-Life)

Quality of Life 101: Important Elements

- Environment
  - Clean air, water, …
- Employment
  - "High Quality" Jobs
  - Correlated with Crime/Personal Safety
- Mobility
  - Safety, Efficiency, Equity, Comfort, Convenience, …
- **Main Premise:**
  - Inevitable that we will Create **Smart Driving Technology**:
    - **Cost (Technology) < Net Present Value { Expected [Reduced Liability (Technology)]}**
      -> Insurance can pay for adoption of the technology AND make more money,
  - "High Quality" Jobs are created,
  - Mobility is enhanced,
  - Lives are saved, injuries avoided and disruption averted, …
  - Environment is improved
  - All for **FREE**!

Problem Statement

- Two objectives
  - **1. Safety**: We are killing, Injuring and Causing way too much property damage in delivering **mobility to individuals**

What Problem are/should we be addressing

- Deaths/yr.: ~ **38K** US; ~**1.25M** World

- Leading cause of death for ages of **5 -> 35**

- Driving: One of the most dangerous occupations
  - Worse than coal mining

- NHTSA: Car Crashes cost US **$871B/yr** **(~ $2,800/person** 5/29/14)
  - (**$2.8K/person**); 1/3 Cash

- > **90%** involve Human error

- The Bad news (Safety Council's Press release): **Things are getting worse!**

Early Estimate of Motor Vehicle Traffic Fatalities in 2012

Quarter	1st Quarter (Jan–Mar)	2nd Quarter (Apr–Jun)	3rd Quarter (Jul–Sep)	4th Quarter (Oct–Dec)	Total (Full Year)
Fatalities and Percentage Change in Fatalities for the Corresponding Quarter From the Prior Year					
2005	9,239	11,005	11,897	11,369	43,510
2006	9,558 [+3.5%]	10,942 [-0.6%]	11,395 [-4.2%]	10,813 [-4.9%]	42,708 [-1.8%]
2007	9,354 [-2.1%]	10,611 [-3.0%]	11,056 [-3.0%]	10,238 [-5.3%]	41,259 [-3.4%]
2008	8,459 [-9.6%]	9,435 [-11.1%]	9,947 [-10.0%]	9,582 [-6.4%]	37,423 [-9.3%]
2009	7,552 [-10.7%]	8,975 [-4.9%]	9,104 [-8.5%]	8,252 [-13.9%]	33,883 [-9.5%]
2010	6,755 [-10.6%]	8,522 [-5.0%]	9,226 [+1.3%]	8,496 [+3.0%]	32,999 [-2.6%]
2011	6,708 [-0.7%]	8,216 [-3.6%]	8,960 [-2.9%]	8,483 [-0.2%]	32,367 [-1.9%]
2012[†]	7,550 [+12.6%]	8,650 [+5.3%]	9,250 [+3.2%]	8,630 [+1.7%]	34,080 [+5.3%]

What Problem are/should we be addressing

**Press Release on Feb 16, 2016:**

NSC Motor Vehicle Fatality Estimates
Prepared by the Statistics Department
National Safety Council

Motor-vehicle deaths up 8% in 2015.

With continued lower gasoline prices and an improving economy resulting in an estimated 3.5% increase in motor-vehicle mileage, the number of motor-vehicle deaths in 2015 totaled 38,300, up 8% from 2014. The 2015 estimate is provisional and may be revised when more data are

http://www.nsc.org/NewsDocuments/2016/mv-fatality-report-1215.pdf

Figure 1
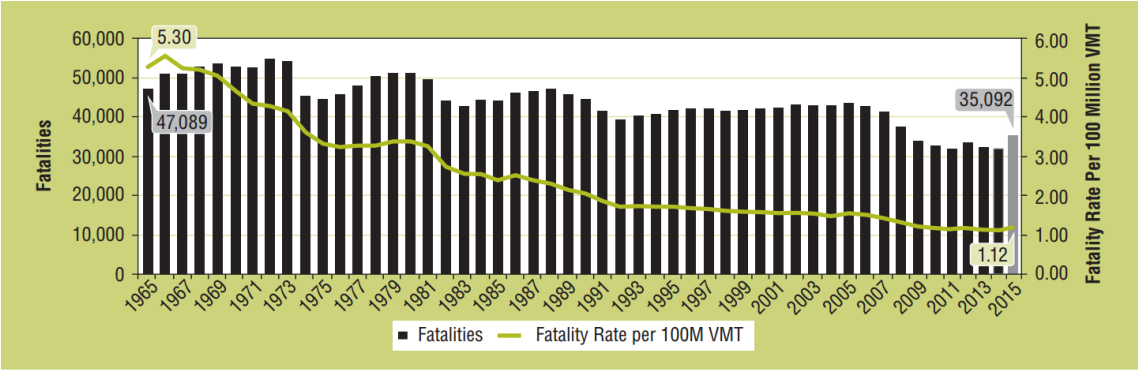**Percentage Change in Total Traffic Fatalities, 1965–2015**
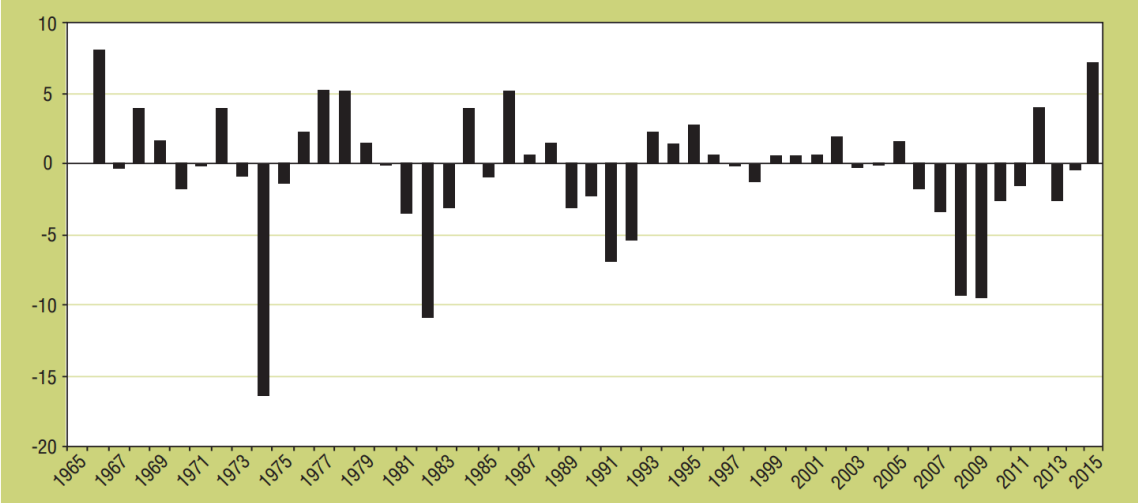
Sources: 1965–1974: National Center for Health Statistics, HEW, and State Accident Summaries (Adjusted to 30-Day Traffic Deaths by NHTSA); FARS 1975-2014 Final File, 2015 Annual Report File (ARF)

Figure 2 shows the number of fatalities and the fatality rate per 100 million VMT since 1966. The 2015 fatality count (35,092) is the highest number since 2008. In 2015 an estimated 2.44 million peopl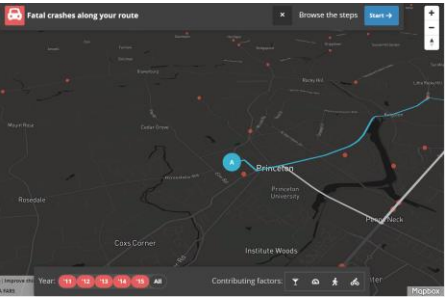e were injured in motor vehicle traffic crashes, com-pared to 2.34 million in 2014 as shown in Figure 3 according to NHTSA's National Automotive Sampling System (NASS) General Estimates System (GES), a statistically significant increase of 4.5 percent.

Figure 2
Fatalities and Fatality Rate per 100 Million VMT, by Year, 1965–2015

Sources: 1965–1974: National Center for Health Statistics, HEW, and State Accident Summaries (Adjusted to 30-Day Traffic Deaths by NHTSA); FARS 1975-2014 Final File, 2015 Annual Report File (ARF); Vehicle Miles Traveled (VMT): FHWA.

[Open data and traffic fatalities](#)

Week 8
https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812318

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The Problem....
We Love the Car's Freedom & Mobility

But...Continuous Vigilance is an unrealistic requirement for drivers

TravelTainment Industry Wants Everyone'sAttention

THE RELATIVE FREQUENCY OF UNSAFE DRIVING ACTS IN SERIOUS TRAFFIC CRASHES

Summary Technical Report

By D. L. Hendricks, Veridian Engineering, Inc.
J. C. Fell, Star Mountain, Inc.
M. Freedman, Westat, Inc.

Contributing Authors:

> "In 717 out of 723 crashes (99%), a driver behavioral error caused or contributed to the crash"

- **DRIVER INATTENTION** — 22.7%
- **VEHICLE SPEED** — 18.7%
- **ALCOHOL IMPAIRMENT** — 18.2%
- **PERCEPTUAL ERRORS** (e.g. looked, but didn't see) — 15.1%
- **DECISION ERRORS** (e.g. turned with obstructed view) — 10.1%
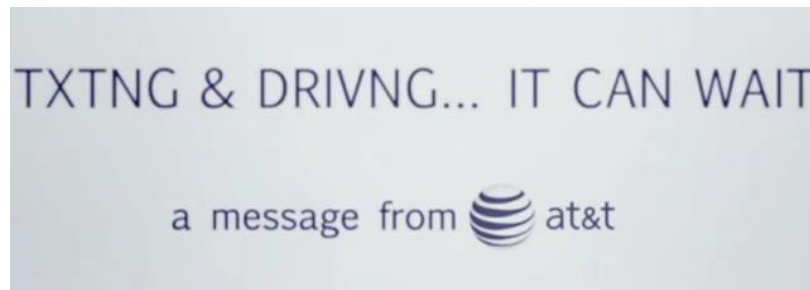- **INCAPACITATION** (e.g. fell asleep) — 6.4%

Txtng while driving is out of control...

Response is Laudable

DRIVE AND TEXT?

EXPECT THIS NEXT

Take the NO PHONE ZONE PLEDGE
Additional information at:
http://www.palmbeachstate.edu/x19600.xml

FLORIDA ASPIRA
An Investment in Latino Youth

PALM BEACH STATE COLLEGE

TXTNG & DRIVNG... IT CAN WAIT

a message from at&t

Text Talk TICKET
Hang Up & Drive

Save yourself a $124 ticket — and save lives!
Kirkland, WA

April 3: US DOT Launches First-Ever National Distracted Driving Enforcement and Advertising Campaign

But... Not Likely to be Effective

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CARTS
The Center for Automated Road Transportation Safety

Up to today:
safety addressed using
Crash Mitigation
(air bags, seat belts, crash worthiness, …)

Can
Automated Vehicle Technology
Help???

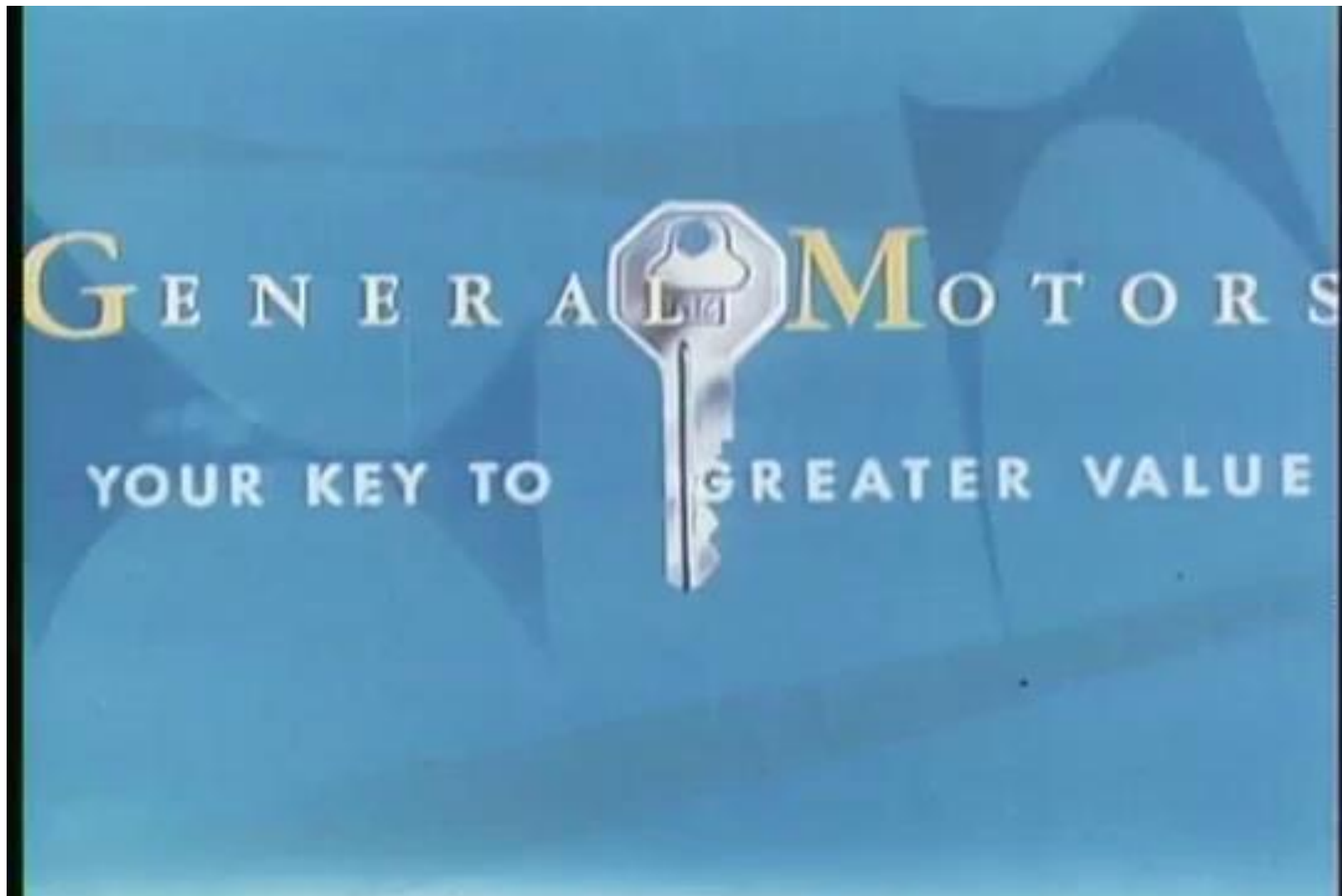**AHS: Automated Highway Systems: 1939 - 1997**
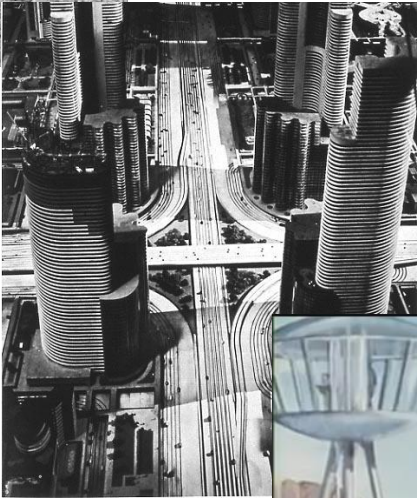
Play video

At one time we thought….

NOT: Future Vehicle Technologies

NOT: Future Vehicle Technologies

NOT: Future Vehicle Technologies

NOT: Future Vehicle Technologies

Evolution of AHS Concept

- AHS Studies by FHWA in late 70's and mid 90's

2004

2005

2007

2005

2007

[Link to Presentation](#)   [Not Easy](#)   [Old House](#)   [2005](#)   [2007](#)

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- Why:
  - **Problem statement**
    - Safety, Personal Pleasure & Mobility (Quality-of-Life)
- What & When:
  - Levels of "**Smart**ness"
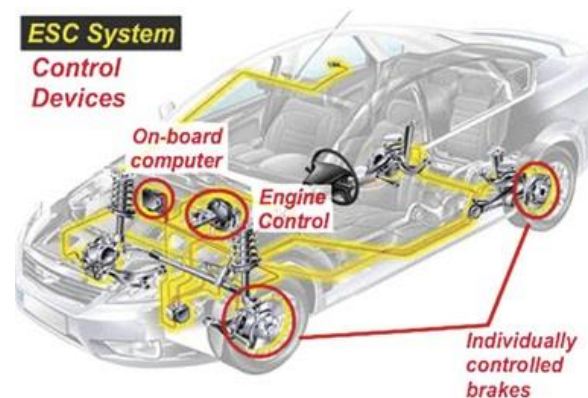   - **'Safe-driving Car', 'Self-driving Cars' & 'Driverless Cars'**

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Making Sure We Are Using the Same Terminology…

- **Lots of confusion… 'Connected'; 'Autonomous', 'Automated', '4 NHTSA Levels' '5 SAE Levels'…**
- **Only 3 kinds:**
  - **'Safe-Driving Cars… (Trucks or Buses)'**
    - **Always on Automated Emergency Braking & Lane Centering**
    - **Delivers: Safety**
      - **Needs Insurance to Promote Wide-spread Adoption w/o Government Mandate**

2016 Kia forte

'Safe-Driving Cars'… All About SAFETY

- **On… ALL the Time** (in the background, watching, waiting…)
- **To 'Bail out' Drivers when they do something 'stupid'…**
- **We already accept some of this automated technology…**
  - **Anti-lock Brakes**
  - **Electronic Stability Control**

Both: Override the driver and "Do the right thing"
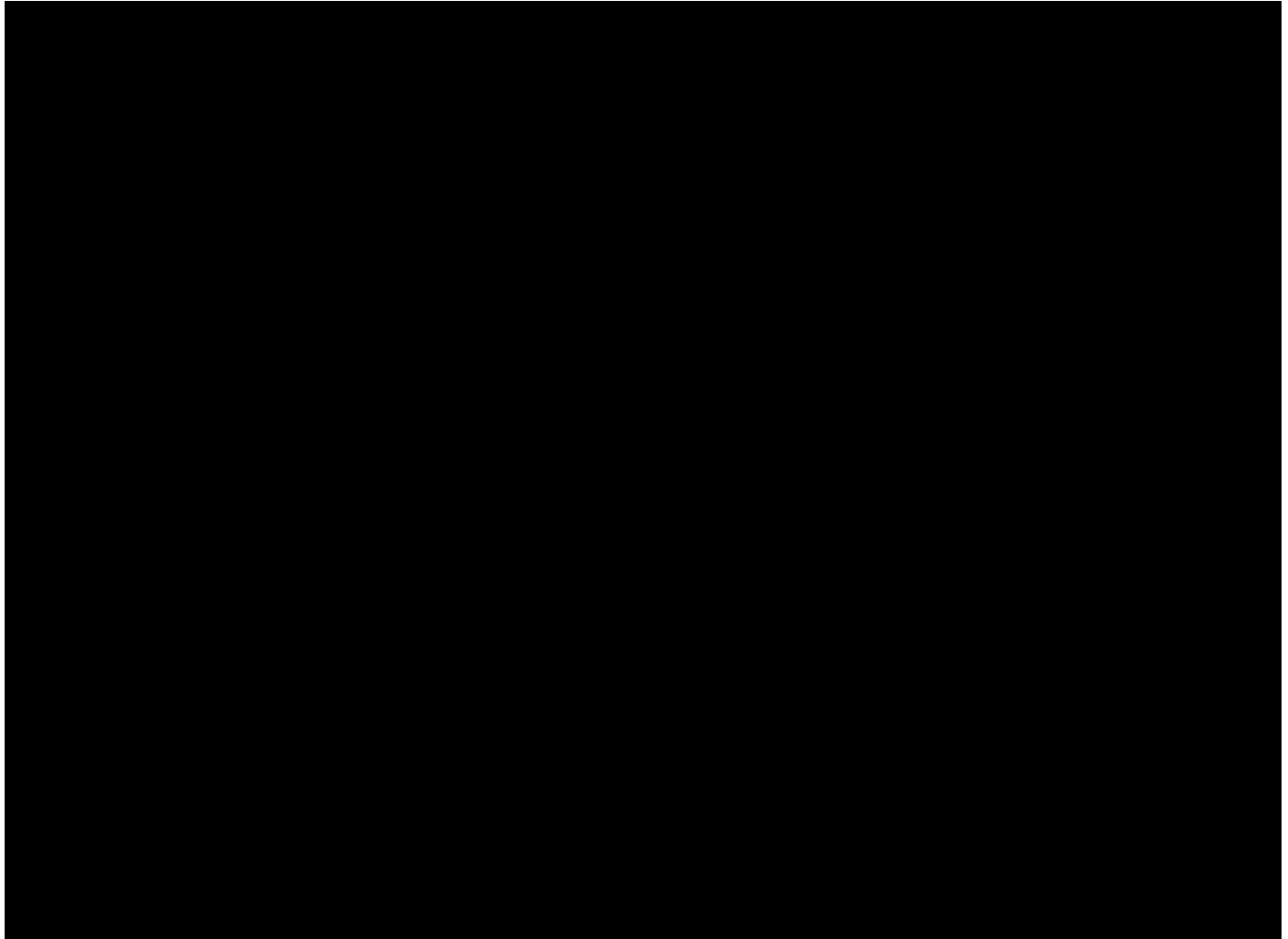
'Safe-Driving Cars'… All About SAFETY

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- **We already accept some of this…**
  - **Anti-lock Brakes**
  - **Electronic Stability Control**
  - **Extend these to…**
    - **Don't run into things**

Fundamental AV Concept

Fundamental AV Concept

Fundamental AV Concept

Professional driver. Closed course.

'Safe-Driving Cars'… All About SAFETY

- **On… ALL the Time** (in the background, watching, waiting…)
- **To 'Bail out' Drivers when they do something 'stupid'…**
- **We already accept some of this…**
  - **Anti-lock Brakes**
  - **Electronic Stability Control**
  - **Extend these to…**
    - Don't run into things
  - **Unfortunately, some on the market don't work well…**

	12 mph test			25 mph test				Forward collision warning
Speed reduction (mph)	less than 5	5 to 9	10 or more	less than 5	5 to 9	10 to 21	22 or more	n/a
Points	0	1	2	0	1	2	3	1

Speed reduction in 12 and 24 mph tests

Volvo S60
2 point advanced

Dodge Durango
3 point advanced
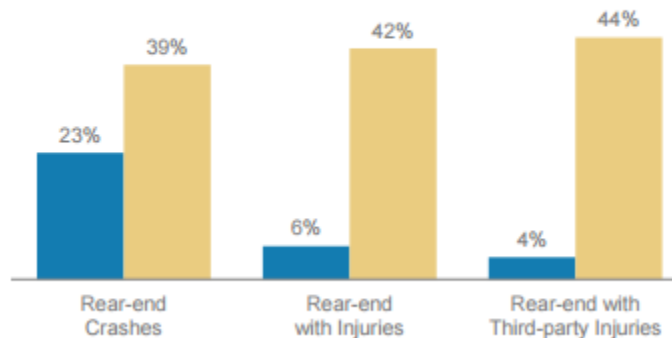
Subaru Outback
6 point superior

ADAS Deep Dive: Current Effectiveness and Penetration Levels

Feb 1, 2017

Exhibit 13:
Reduction of Rear-end Striking Crash Involvements
■ FCW ■ FCW & AEB

- Rear-end Crashes: FCW 23%, FCW & AEB 39%
- Rear-end with Injuries: FCW 6%, FCW & AEB 42%
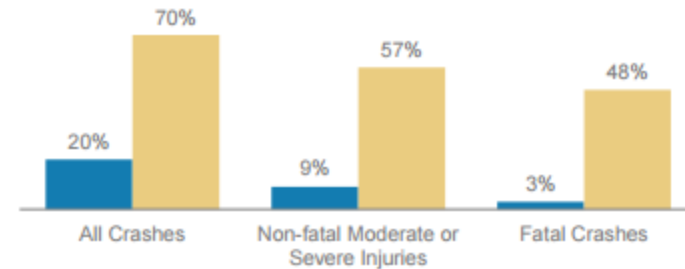- Rear-end with Third-party Injuries: FCW 4%, FCW & AEB 44%

Source: IIHS, Morgan Stanley Research

Exhibit 14:
Potential Crash Prevention/Mitigation Rates of Front Crash Prevention Systems
■ Front-end ■ Rear-end

- All Crashes: Front-end 20%, Rear-end 70%
- Non-fatal Moderate or Severe Injuries: Front-end 9%, Rear-end 57%
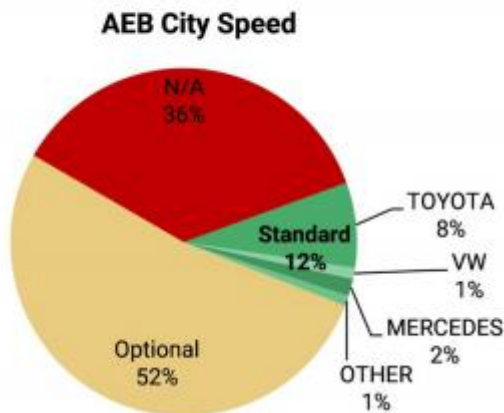- Fatal Crashes: Front-end 3%, Rear-end 48%

Source: Accident Analysis & Prevention, IIHS, Morgan Stanley Research

One could reasonably argue that if a technology can save 10k or 20k lives and hundreds of thousands of injuries per year in the US it should be (1) affordable and (2) not be optional equipment. **Contrary to this, we found the majority of models currently available either do not offer active safety features or offer them only as optional equipment at prohibitively high costs. Our key takeaways are summarized below:**
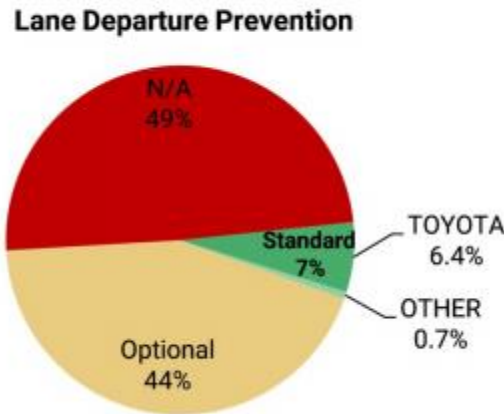
Exhibit 16:
Toyota dominates standard AEB equipment

AEB City Speed

N/A 36%
TOYOTA 8%
Standard 12%
VW 1%
MERCEDES 2%
Optional 52%
OTHER 1%

Exhibit 17:
50% of vehicles sold do not offer lane departure prevention technology

Lane Departure Prevention

N/A 49%
Standard 7%
TOYOTA 6.4%
OTHER 0.7%
Optional 44%

Only 12% of vehicles sold in the US year-to-date are equipped with standard AEB, of which 2/3 (8% of overall vehicles sold) are made by Toyota. Total cost safety ownership ranges between an additional 2.5% (or $900) on top of base vehicle MSRP up to 60% (or $18,220)
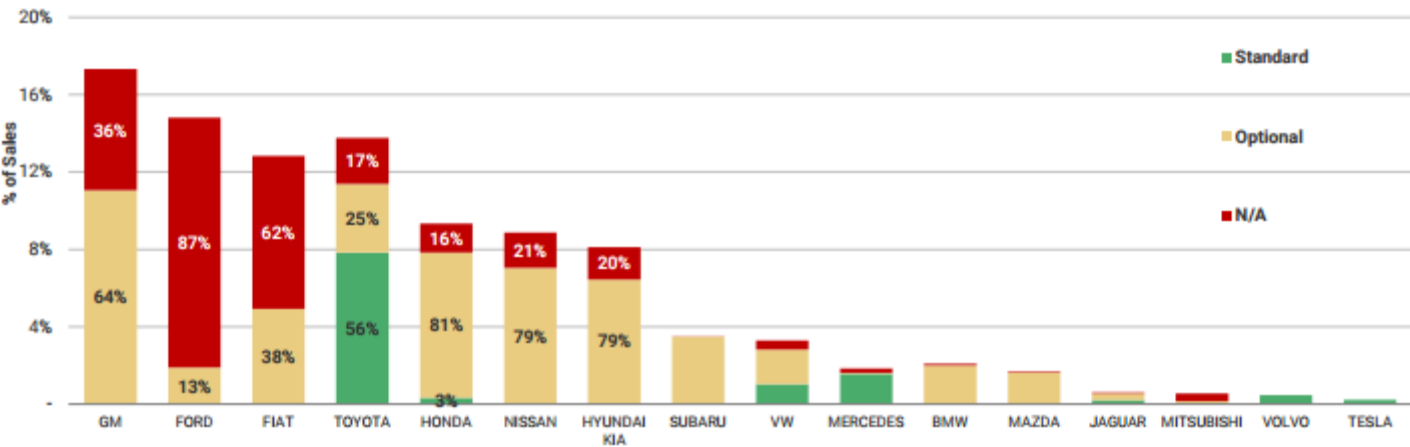
We also observed that safety package options are often only available on top-tier trims within a model.
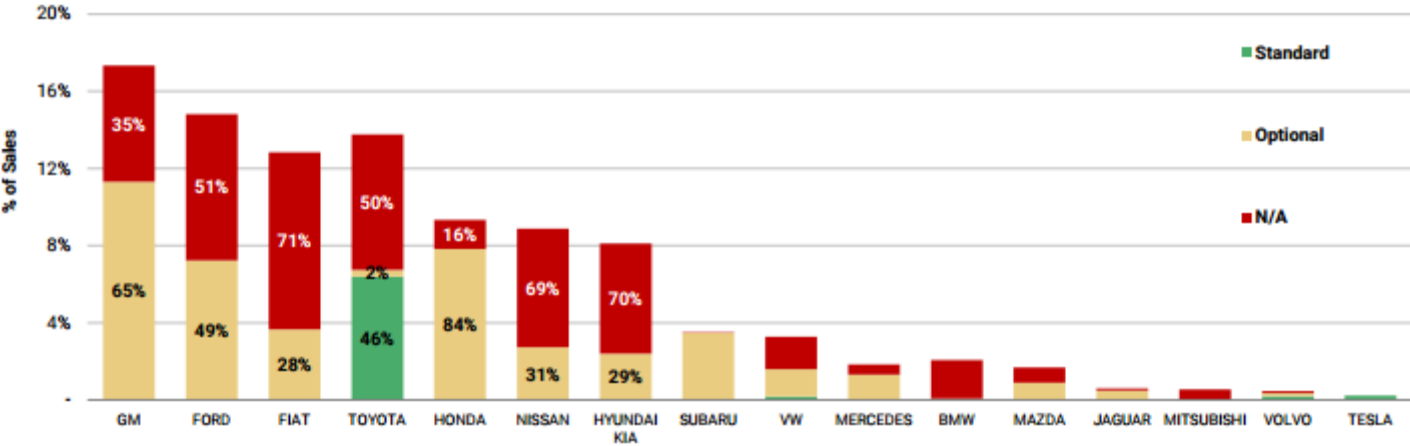
None of GM, Ford or Fiat offer standard active safety equipment on models sold this year.

Exhibit 18:

Distribution of AEB City Speed availability by OEM

Source: Autodata, Consumer Reports, Morgan Stanley Research

Exhibit 19:

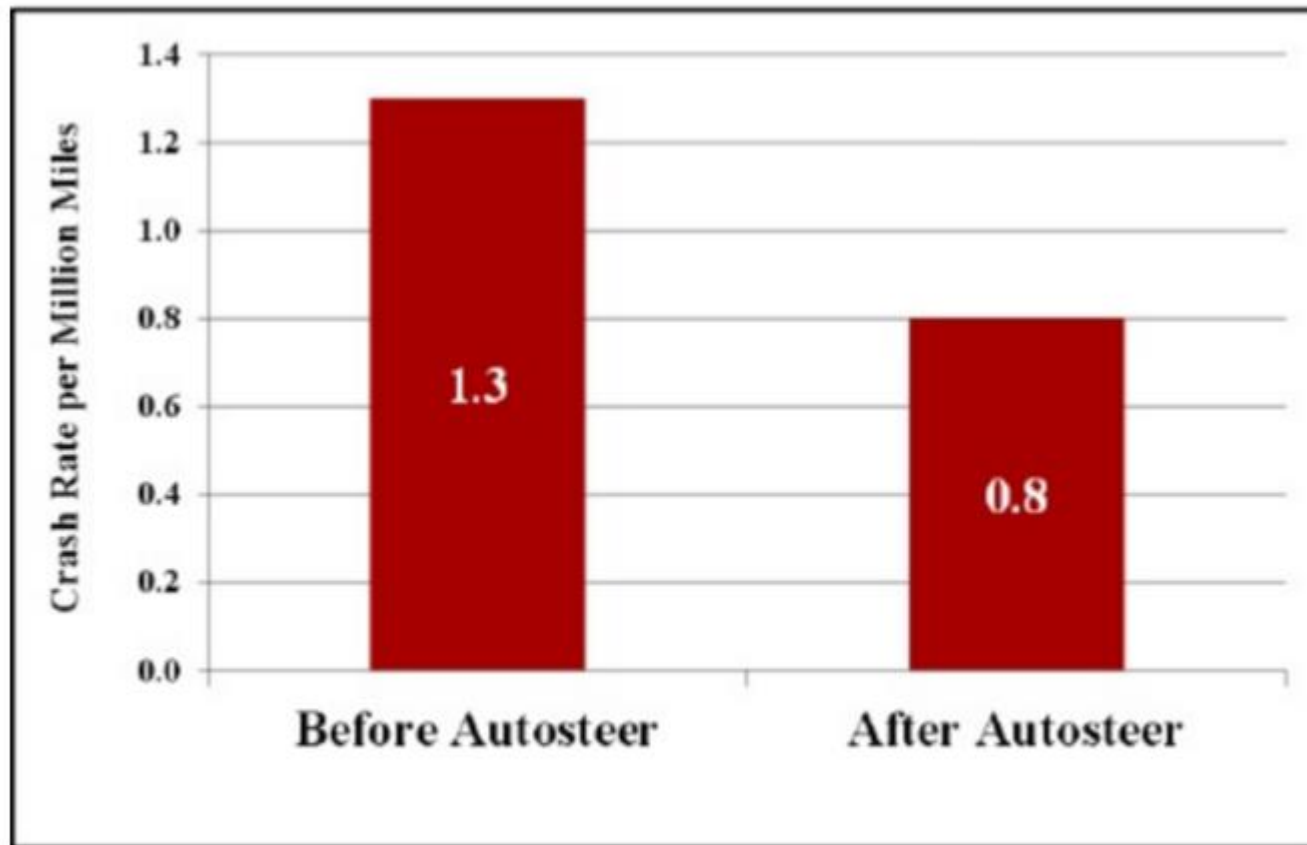Distribution of Lane Departure Prevention availability by OEM

Source: Autodata, Consumer Reports, Morgan Stanley Research

NHTSA's full final investigation into Tesla's Autopilot shows 40% crash rate reduction

Posted Jan 19, 2017 by Darrell Etherington (@etherington)

Figure 11. Crash Rates in MY 2014-16 Tesla Model S and 2016 Model X vehicles Before and After Autosteer Installation.

Why should Safety Advocates Focus on 'Safe-Driving Cars' ???

- **They 'Bail out' Drivers when they do something stupid..**

- **We already accept some of this...**
  - Anti-lock Brakes
  - Electronic Stability Control
  - **Extend these to...**
    - Don't run into things
    - Don't depart from the lane unless you signal
    - **No Crazy speeding**
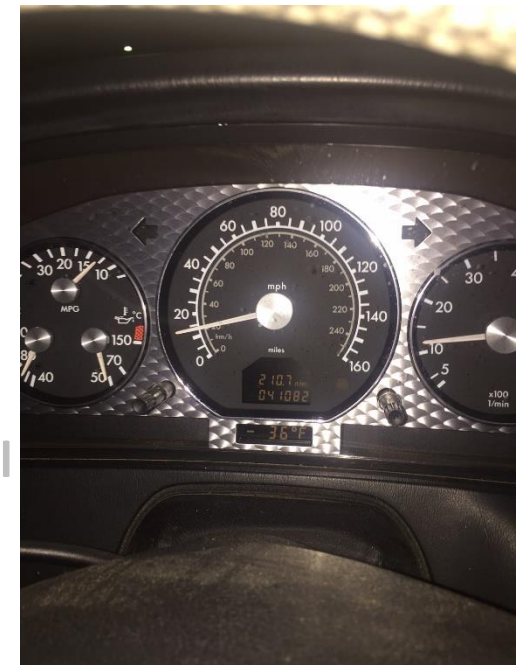
Why should Safety Advocates Focus on 'Safe-Driving Cars' ???

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  - Extend these to...
    - Don't run into things
    - Don't depart from the lane unless you signal and it is safe
    - No Crazy speeding

- **Should be able to reduce Collisions by > 50%**
  - **Make real progress towards VISION ZEROs**
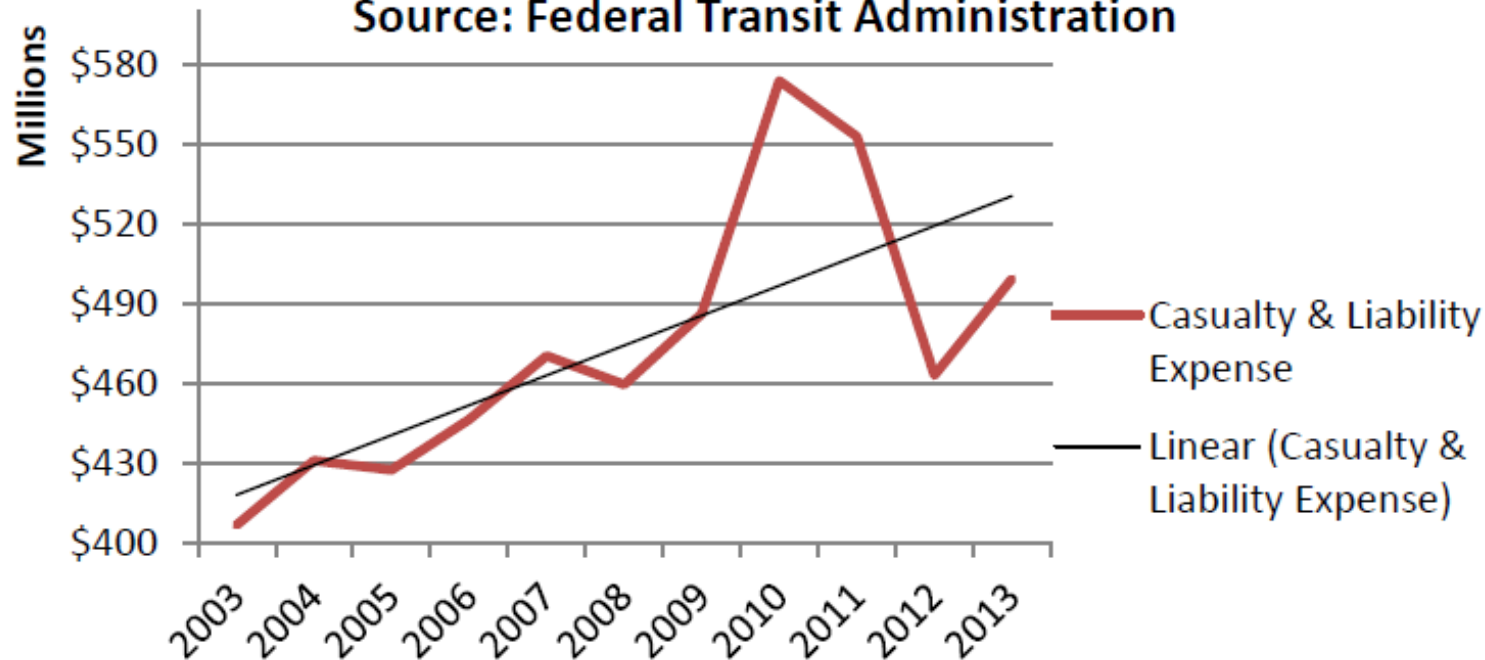 - **Print $$$$ for Fleet operators and Insurance companies**

They Print $$$$...
Example from Transit Industry...

US Bus and Paratransit Data 2003-2013
Casualty & Liability Expense

Source: Federal Transit Administration

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VEHICLE
ENGINEERING

Also… They Print $$$$
Example from Transit Industry…

2013 Nationwide
Bus Casualty and Liability Expense
Source FTA NTD

Casualty and Liability Amount	Vehicle-related	119 Fatalities 15,351 Injuries

Also… They Print $$$$
Example from Transit Industry…

2013 Nationwide
Bus Casualty and Liability Expense
Source FTA NTD

Casualty and Liability Amount	Vehicle-related	119 Fatalities 15,351 Injuries $499,872,628.
Total Buses Commuter Bus (CB), Motor Bus (MB), Bus Rapid Transit (RB), Demand Responsive (DR)		**80,795**
Sub-Total Casualty and Liability Amount Per Bus		**$6,187/Bus/Year**

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CARTS
The Center for Automated Road Transportation Safety

Safe-Driving Cars:
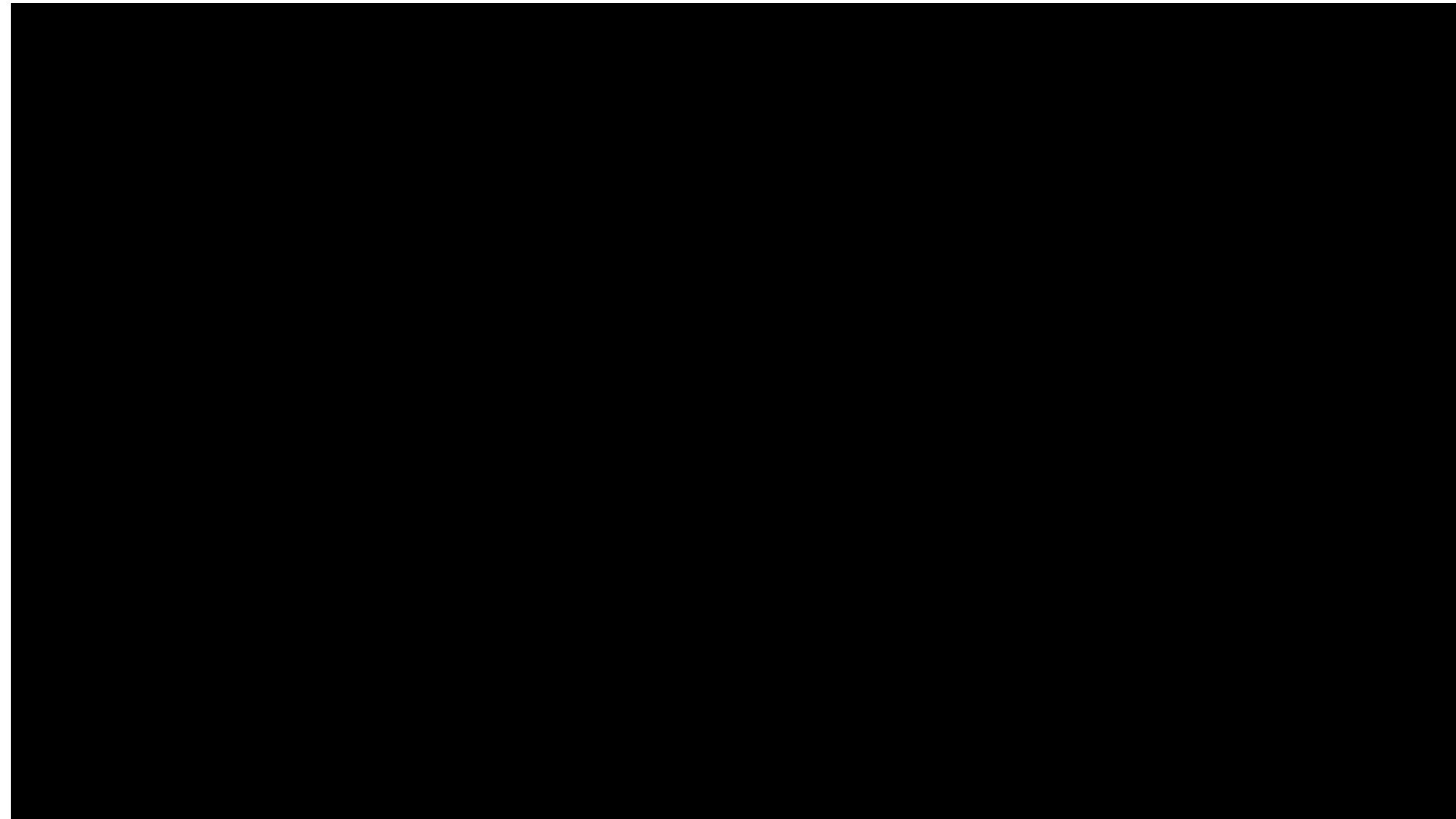## Impact on the Way we do Business

- **Consumers:**
  - Respond to the affordable ADAS-equipped cars and buy Toyota, Volvos, Subarus, Teslas and Benzes
- **Insurance:**
  - Recognize the **LOSS Prevention** of ADAS-equipped cars and especially encourage their higher risk customers to purchase the best ADAS-equipped cars.
- **Public fleet purchasing agents:**
  - Purchase ONLY ADAS-equipped vehicles. Since public entities can't run away from the crash liability exposure, ADAS "prints money"!
- **Public Risk Pools:**
  - Incentivize and insist that purchasing agents buy ONLY the best ADAS-equipped vehicles
    - This is beginning to happen with Transit Risk Pools & Transit Agencies
- **NHTSA/IIHS/Consumer Reports/Public Oversight/???**
  - Establish a consistent naming and stringent rating system for ADAS
- **Auto Manufacturers**
  - Substantially improve the price/performance of their ADAS offerings

Making Sure We Are Using the Same Terminology…

- Lots of confusion… 'Connected'; 'Autonomous', 'Automated', '4 NHTSA Levels' '5 SAE Levels'…

- Only 3 kinds:
  - 'Safe-Driving Cars… (Trucks or Buses)'
    - Always on Automated Emergency Braking & Lane Centering
    - Delivers: Safety
      - Needs Insurance to Promote Wide-spread Adoption w/o Government Mandate
  - 'Self-Driving Cars… (Trucks or Buses)' https://electrek.co/2017/06/12/first-drive-tesla-autopilot-2-0-autopark/
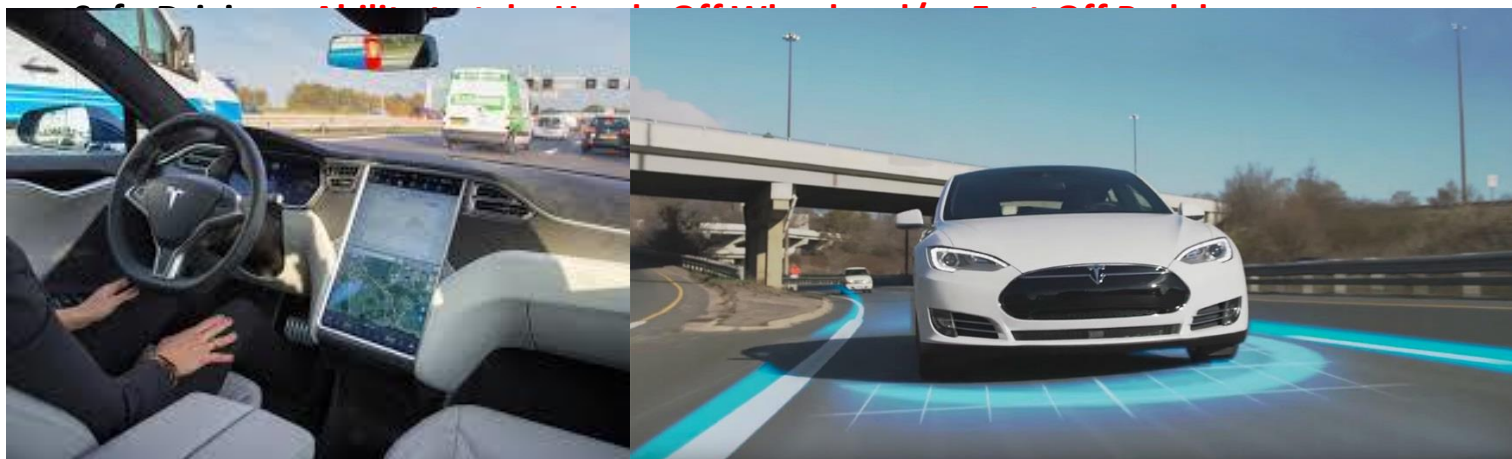
Self-Driving Cars:
Impact on the Way we do Business

- **Consumers:**
  - Will pay almost anything for this feature that "enables texting"
- **Insurance:**
  - Make sure Self-driving doesn't compromise Safety Gains of Safe-driving Cars
- **Public fleet purchasing agents:**
  - Stay away from this technology
- **Public Risk Pools:**
  - Incentivize and insist that purchasing agents buy ONLY Safe-driving cars; Stay away from this technology
- **NHTSA/IIHS/Consumer Reports/Public Oversight/???**
  - VMT is going to go through the roof. Trip lengths will increase as will congestion.
- **Auto Manufacturers**
  - This is their new 21st Century "Corinthian Leather", "Chrome" & "Fins". $$$ ☺

Making Sure We Are Using the Same Terminology...

- 'Self-Driving Cars...'
  - Safe-Driving + Ability to Drive Hands-Off Wheel and/or Feet-Off Pedals
    - On Some stretches of Some Roads at Some Times
  - Delivers: User Convenience + Some Environmental Benefits
- '**Driverless Cars ...** (Cars, Trucks or Buses)
  - **Safe-Driving + Always: Hands-Off, Feet-Off; No Steering Wheel or Pedals**
    - **Sharing Some Streets at Some Times with Conventionally-driven vehicles**
  - **Delivers: Mobility for All + Substantial Environmental Benefits**
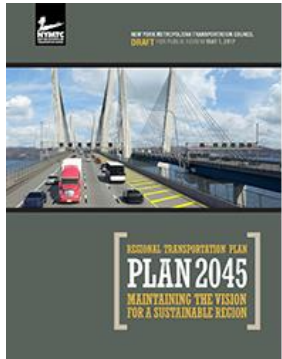
Driverless Cars:
Impact on the Way we do Business

- **Consumers:**
  - Multiple car households in cities and suburbs will decrease enormously and those cars will be used occasionally and NOT in commuting
- **Insurance:**
  - Personal car insurance will decrease by at least a factor of 10.
- **Public/private fleets:**
  - Large Fleets will offer shared-ride on-demand mobility as a service.
  - Affordable high-quality mobility will be available to essentially "all".
    - Young, old, handicapped, those under the influence
- **Public/Private Risk Pools:**
  - Will cover the greatly reduced risk exposure of this form of mobility
- **NHTSA/IIHS/Consumer Reports/Public Oversight/???**
  - A new agency will emerge to provide the public oversight on this new form of mobility
  - Zoning regulations associated with parking will change substantially changing the value and availability of land.
    - Ridesharing will alleviate congestion.
    - Little need for new roads. Much need to maintain existing roads.
- **Auto Manufacturers**
  - May not be the ones manufacturing this form of mobility
  - Local goods movement will be done using drieverless technology

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        - **'Safe-driving Car', 'Self-driving Cars' & 'Driverless Cars'**
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Princeton **University**

PAVE PRINCETON AUTONOMOUS VEHICLE ENGINEERING

Detailed Quantitative Forecasts Assuming Business As Usual

4. **FUTURE CHANGES LIKELY TO IMPACT TRANSPORTATION** Major changes are occurring across the nation and in the NYMTC planning area which are likely to significantly transform the provision, management and use of transportation services and facilities. The drivers of these changes could, and in fact in some cases already are, redefining when, how and why people are traveling and goods are being moved during the planning period. Examples include the following:

- Personal mobility is likely to evolve from vehicle ownership toward increased use of shared, on demand, possibly autonomous vehicles.
- Goods movement is likely to be impacted by technological changes including additive manufacturing (also known as 3D printing), vehicle automation and automated delivery, and the further automation of goods production.

At this writing, it is **impractical to quantitatively predict the impact** that the drivers of change identified above may have on the trends and forecasts in this section of the Plan, as well as the operation of the transportation system in the NYMTC planning area. However, **there is little doubt** that some combination of these drivers will have an impact on either or both demand for transportation and/or the manner in which transportation services are provided. **Impacts will likely also be felt in the way in which transportation planning is accomplished**.

Although quantitative predictions of the impacts of the drivers of change on transportation demand and supply is impractical as of this writing, due mainly to uncertainty about the pace of technological development and its interplay with social adaptive behavior, some qualitative assessments can be made. **For the purposes of Plan 2045, these qualitative assessments will need to be noted until better information on trends and behaviors is quantified**.

CARTS
The Center for Automated Road Transportation Safety

Safe-driving Car (Here Today)

- |
  - **'Safe-Driving Cars... (Trucks or Buses)'**
    - Always on **Automated Emergency Braking & Lane Centering**
    - **Delivers:** **Safety**
      - **Needs Insurance to Promote Wide-spread Adoption w/o Government Mandate**

Safe-driving Car (Here Today)

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  - **'Safe-Driving Cars... (Trucks or Buses)'**
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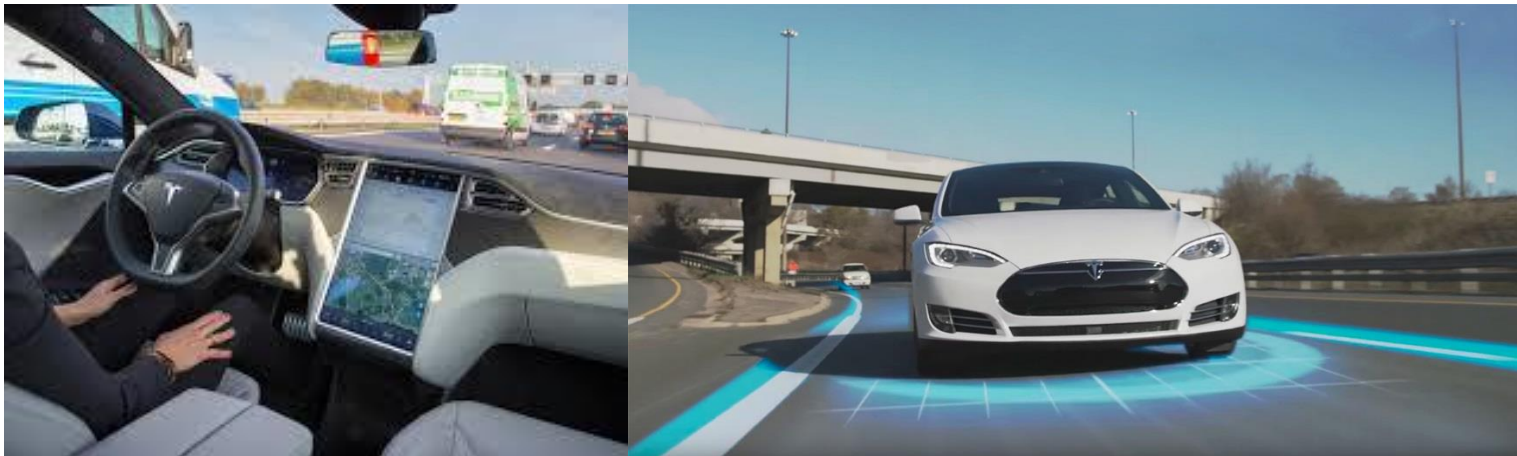

2016 Kia Forte

Safe-driving Car **(Here Today)**

- Most Potent "Vision Zero" Tool

- Promote Consumer Adoption
  - Certainly as enthusiastically as Bike riding in promoted
  - Cost practically zero

- Improve visual striping and visual signage
  - Serves everyone (conventional cars and SmartDrivingCars

Self-driving Car (Here Today)

— **'Self-Driving Cars... (Trucks or Buses)'** https://electrek.co/2017/06/12/first-drive-tesla-autopilot-2-0-autopark/

- **Safe-Driving + Ability to take Hands-Off Wheel and/or Feet-Off Pedals**
  - **On Some Stretches of Some Roads and Some Times**
- **Delivers: User Convenience + some Environmental Benefits**
  - **New 'Chrome & Fins". Auto companies & Car dealers know how to sell these**

Self-driving Car (Here Today)

- Higher VMT

- More Sprawl

- Little MPOs can do for or against
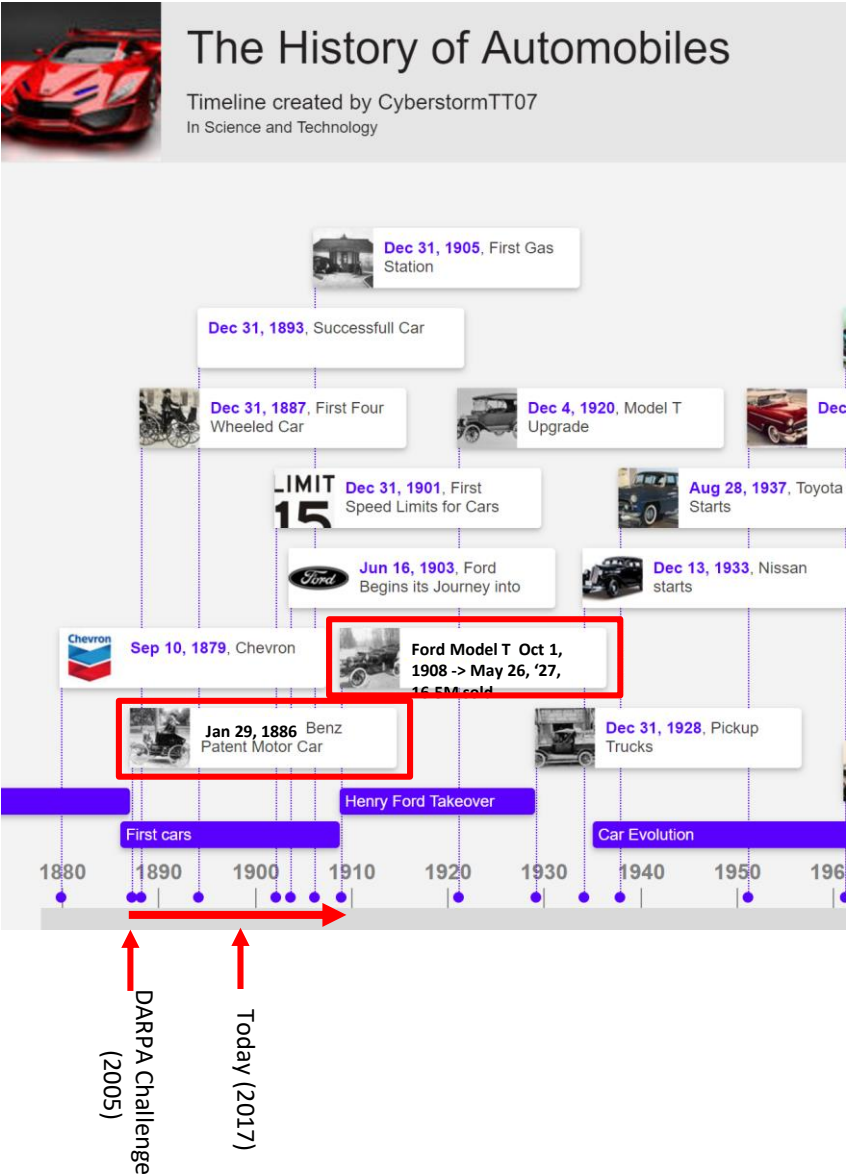 - Market forces too strong favoring Auto Industry

Driverless (Barely started, needs a lot of help)

- 'Driverless Cars ... (Cars, Trucks or Buses)
  - Safe-Driving + **Always: Hands-Off, Feet-Off; No Steering Wheel or Pedals**
    - Sharing Some Streets at Some Times with Conventionally-driven vehicles
  - Delivers: Mobility for All + Substantial Environmental Benefits

Driverless Car... Where are we?

The History of Automobiles
Timeline created by CyberstormTT07
In Science and Technology

Driverless (Barely started, needs a lot of help)

- Auto-ownership will change dramatically.
  - No need for more than one car per household, It will be rarely used
- Activity areas will be served by staging areas and loading/alighting areas rather than the parking of personal vehicles
  - Zoning requirements will change
  - Density requirements will change
- Local commercial delivery will change dramatically
- Mass transit will drastically reduce compressing demand spatially (stations/stops/routes) and temporally (schedules) (become demand responsive)
- We'll be Forced to do something about "Speed Limits"
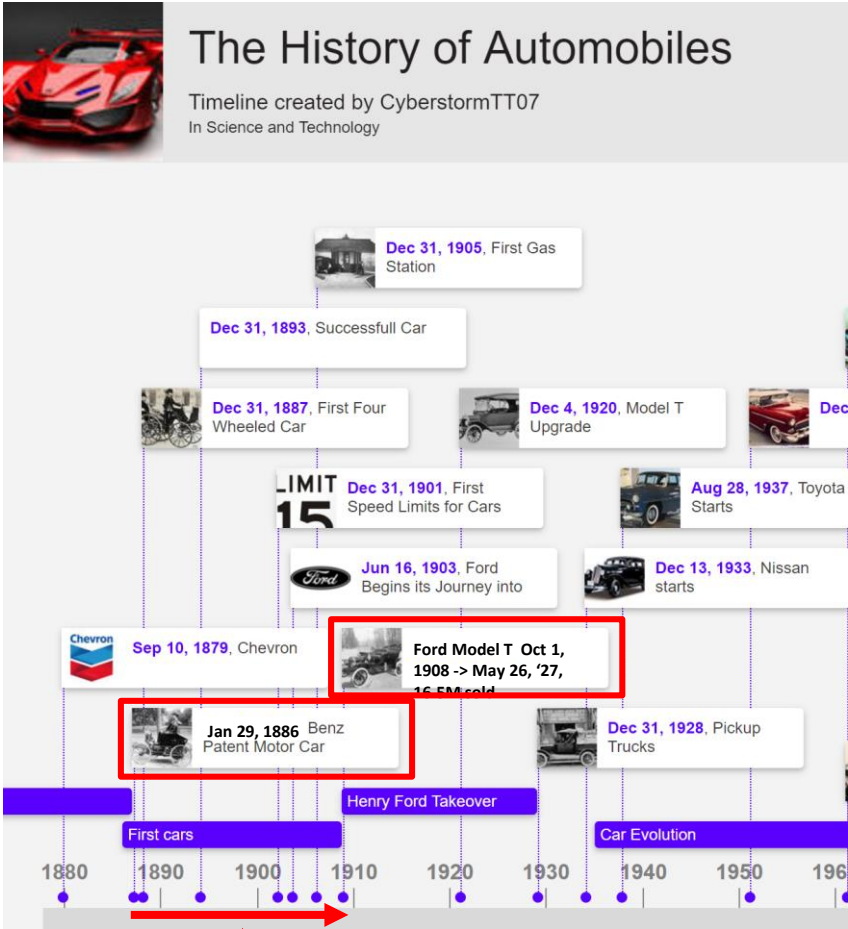 - Need to be harmonized

- and other "Rules of the Road"

Discussion!

Thank You

alaink@princeton.edu

www.SmartDrivingCar.com

Driverless Car... Where are we?

The History of Automobiles

Timeline created by CyberstormTT07
In Science and Technology

a Mobility Perspective on SmartDrivingCars:

- **Where/When …under well-defined circumstances… each car can drive itself (no human intervention)**
  - **'Yesterday', ALL CIRCUMSTANCES required a licensed driver**
    - **Let's represent these CIRCUMSTANCES with a red dot**

  - **Today/tomorrow, there will be SOME CIRCUMSTANCES where/when the car drives itself at the discretion of the licensed driver**
    - **Let's represent these CIRCUMSTANCES with a Blue dot**

  - **There are OTHER CIRCUMSTANCES where/when the car drives itself irrespective of the driver's discretion**
    - **Let's represent these CIRCUMSTANCES with a Green dot**

Implications of SmartDrivingCars

Type of SmartDrivingCar	Insurance Implications	Value Proposition (driver/buyer)	Market Force (who/what)	Societal Implications

Implications of SmartDrivingCars

Type of SmartDrivingCar	Insurance Implications	Value Proposition (driver/buyer)	Market Force (who/what)	Societal Implications
Before: "55 Chevy"	Many Accidents, High Claims	Freedom Life Style	Market Dominance (Madison Avenue)	Death trap

Implications of SmartDrivingCars

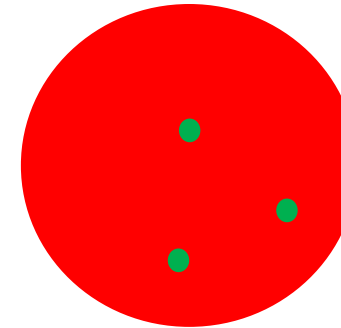| Type of SmartDrivingCar	Insurance Implications	Value Proposition (driver/buyer)	Market Force (who/what)	Societal Implications
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0+ "Crash Mitigation" (air bags, seat belts, energy absorbing)	Many Accidents, Higher Claims	Disdain	Public sector; Law enforcement	Fewer deaths

I write tickets to save lives. CLICK IT OR TICKET. ARRIVE ALIVE DE

Implications of SmartDrivingCars

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Safe-driving Cars: (Automated Collision Avoidance Systems) (On ALL the time)				

A Mobility Perspective on SmartDrivingCars:

- *"Safe-Driving Car"* **(or Truck or Bus)**

  (aka AutomatedCollisionAvoidance…)

  – *'Circumstances' :* from the beginning of a crash-imminent location/time and to a 'safe haven' location/time.

Positioned for *Viral Adoption* of Safe-Driving Cars

- One only needs to get the **Safe-Driving Car** technology to **'work'** on a 'single' vehicle to initiate **viral adoption**!
  - Definition of **'work'**:

<p style="text-align:center"><strong style="color:red">Cost of the Technology</p>

<p style="text-align:center"><</p>

<p style="text-align:center"><strong style="color:green">Net Present Value { Expected Liability Savings _{delivered by that technology}}</p>

- Since the technology
  - Does **NOT** require any infrastructure costs
  - Involves mostly 'Moore's Law' Elements
- The inequality will be achieved and
  - **Insurance** will fuel the viral adoption.

NYSAMPO

CARTS
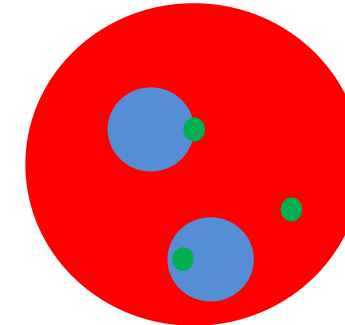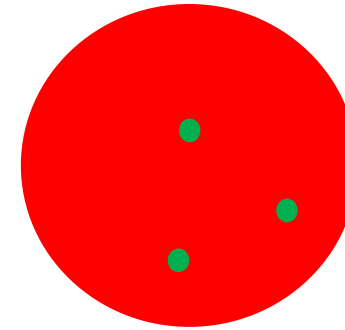The Center for Automated Road Transportation Safety

Implications of SmartDrivingCars

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2. Self-driving Cars: "Ultimate Texting Machine" (Safe-Driving + Lane Changing & Centering, Intersection Control)	A little less $ liability (~Product liability) ++ profits	Liberation (some of the time/places) ; more Safety	Consumers Pull, TravelTainment Industry Push	++ Car sales, flat Insurance claims, ++ VMT

'Self-Driving Cars' Available Today

#1: Tesla S AutoPilot (~$2.5K -> $8K.) See Video 1, and Video 2

   Very Good Lane Centering, Jam Assist, Driverless Parking, Indication that AutoPilot reduces 50% of crashes

#2: MB Dystronic Plus (~$2.8K)

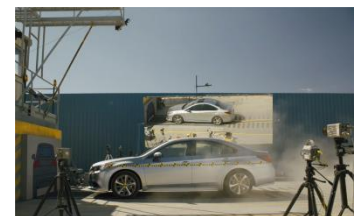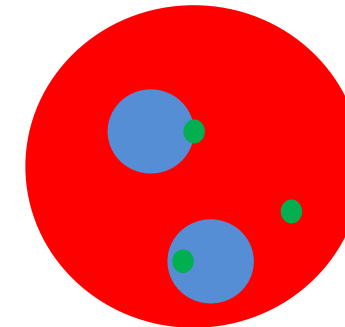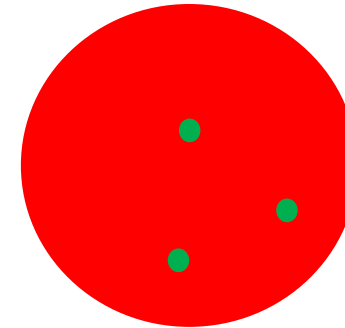   Poor Lane Centering, Very good Jam Assist and Intelligent Cruise Control

#3: Volvo S90 (Standard Equipment; See video)

   OK Lane Centering, Very good Jam Assist and Intelligent Cruise Control

#4: Subaru Eyesight (~$3K) (See Video)

   Just Lane Departure Warning, Very good Intelligent Cruise Control, Obtained Superior Rating from IIHS

Others: BMW & Nissan

Uber launches self-driving cars in Pittsburgh

http://video.cnbc.com/gallery/?video=3000550995

Wednesday, September 14, 2016

A Mobility Perspective on SmartDrivingCars:

- *"Safe-Driving Car"* (or Truck or Bus)

  (aka AutomatedCollisionAvoidance...)

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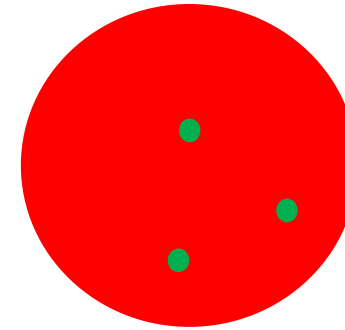 – *'Circumstances' :* **NOT** necessarily places where the use of this car begins and/or ends.

How do we get to…"Driverless"…

- What if "Tesla's AutoPilot" was **improved** to an extent that a **driver** was **unnecessary** for the **entire** trip.

  – Just needs better software (Incremental Cost$_{software}$ -> \$0.00)

  – Then….

A Mobility Perspective on SmartDrivingCars:

- *"Safe-Driving Car"* **(or Truck or Bus)**

  (aka AutomatedCollisionAvoidance...)

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  TESLA

- *"Driverless Car"* **(or Truck or Bus)**

  – *'Circumstances' :* MUST necessarily encompass places where the use of this car begins AND ends.

    - Driverless Vehicles CAN reposition themselves empty

Google

CARTS
The Center for Automated Road Transportation Safety

Implications of SmartDrivingCars

Level	Insurance Implications	Value Proposition (driver/buyer)	Market Force (who/what)	Societal Implications
0	Many Accidents	Freedom Life Style	Market Dominance (M	Death trap
0- bag		Disdain	La	
A Au Co		ne Comfort	Will n & th in	ents;
S Te (AC Intersection Control) **L2,3**	(~Product liability) ++ profits	ration (some e time/places) nore Safety	C Travel	,
3 Driverless Cars: 'aTaxi' Able to 'Empty Reposition' can deliver 'Mobility as a Service' (MaaS)	**Fleet coverage;** (~Product liability)	**Chauffeured, Mobility Bought "by the Drink" rather than "by the Bottle"**	**LaborCost -> 0 Profitable Business Opportunity for Utilities/Transit Companies**	**Personal Car = "Bling"** not instrument of personal mobility, **Comm. Design ++; PMT ?; VMT - -,** Energy - -, Congestion - -, Environment ++

Enhanced Mobility From "Driverless"

- Substantially Cheaper Mobility for those that Can't (or Choose not to) Drive
  - Young (10->15)
  - Too Old
  - Visually Impaired
  - Those under the influence

  - (Today, these folks have access to Taxicabs, Uber, Para-transit that have Mobility-on-Demand like the personal automobile, **BUT** they MUST pay for a driver; whereas everyone else can simply use their time and skill.)

Princeton University

Who Benefits From What?

'Safe-Driving' Car:
(Automated Crash Avoidance Systems;):
Safety, Comfort & Convenience

An **Insurance Profitability** Play

'Self-Driving' Car :
Pleasure, Safety, Comfort & Convenience

An **Enormous Consumer** Play

'Driverless' Car :
Pleasure, Mobility, Efficiency, Equity
*Labor -> $0.00 : Revolutionizes "Mass Transit" by Enabling Low-cost Mobility to **very small** groups of riders*

A **Corporate Utility/Fleet** Play

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Outline

- SmartDrivingCars (aka automated / autonomous / ... vehicles) :
  - Problem statement
    - Safety & Mobility
- What:
  - 'Safe-Driving'; 'Self-Driving'; 'Driverless'
- How do we get Smarted with Driverless
  - Marketplace & External Forces

Get Started with Viral Adoption

Cost of the Technology

$<$

Net Present Value { Expected Liability Savings delivered by that technology**}**

– **Insurance** will/should fuel the viral adoption of **Safe-DrivingCar**

– **Self-Driving** ('Ultimate Texting Machine') **Sells itself**!

  • Auto Industry all over this!! (25% Consumer Electronics Show (CES) about this)

How do we get to "*Driverless*" Vehicles

- ## So…

  We can either: Improve "Tesla AutoPilot"….

  so that it operates essentially on "all" roads in "all" conditions

  (The more roads and the more conditions the more customer "Mobility-on-Demand" trips that can be served, the more the customer will "depend" on the Driverless "autonomousTaxi (aTaxi)" Service.)

  Or, **slow down** enough and choose roads that are "**easy**" (naturally constrained) to begin offering Mobility-on-Demand with low-speed **aTaxis** and grow from there.

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Today's Low-speed *"Driverless"* Vehicles

- Easy Mile

- 2GetThere

- robosoft

- Catapult

- Meridian Shuttle

- Google Self-driving car

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aTaxis: Become Tomorrow's MasS Transit System

- Driverless vehicles that are capable of mixed use operation on essentially every street, road and highway.

Uncongested Mobility for All
New Jersey's Area-wide aTaxi System

ORF 467
Professor Alain L. Kornhauser

Iris Chang '13
Christina Clark '13
JingKang Gao '13
Damjan Korac '13
Brett Leibowitz '13
Philip Oasis '13
Zixi Xu '13
Jaison Zachariah '13
Natasha Harpalani '14
Eileen Lee '14
Alice Lin '14

Aria Miles '14
Hannah Rajeshwar '14
Lucia Wang '14
Charquia Wright '14
Kristin Bergeson '15
Franklyn Darnis '15
Matthew Shackleford '15
Sonia Skoularikis '15
Roger Sperry '15
Andrew Swoboda '15

Operations Research and Financial Engineering
Princeton University
Fall 2012 - 2013

- A Fleet of ~ 1M aTaxis could serve NJ's 28M daily vehicle-borne personTrips

- Average (daily) Vehicle Occupancy (AVO)

    goes from today's 1.0 -> 2.0

- $AVO_{PeakHour;PeakDirection}$

    goes from today's 1.0 -> 3.0+

    Congestion is Eliminated!

- Ridership on NJ Transit Rail increase five (5)-fold
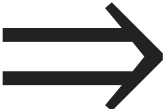
Fundamental aTaxi Concept

$$\$_{new} = \frac{\$_{now}}{5}$$

$$\$_{Capital} = ZERO!$$

$$A_{new} = \frac{A_{now}}{AVO}$$

$$_{new} = \frac{_{now}}{AVO}$$

$$\$_{new} = \frac{\$_{now}}{5 \times AVO}$$

aTaxis: Become Tomorrow's MasS Transit System

- Driverless vehicles that are capable of mixed use operation on essentially every street, road and highway.
  - **Not likely** to evolve from any low speed driverless **except** Google's
  - **Not likely** to evolve from any conventional manufacturer **except** Tesla
    - While Daimler and others could… The business model…Fleet-based, shared-use, shared-ride is too disruptive.

aTaxis: Become Tomorrow's MasS Transit System

- Driverless vehicles that are capable of mixed use operation on essentially every street, road and highway.
  - Not likely to evolve from any low speed driverless except Google's
  - Not likely to evolve from any conventional manufacturer except Tesla
    - While Daimler and others could… The business model…Fleet sales, shared-use, shared-ride is too disruptive.
  - Needs a new vision to disrupt the $10T/yr world mobility market.
    - Google: Advertising opportunities fund the whole transformation
    - Apple: Has cash and needs a new market
    - Amazon: aDelivery… labor free "last mile logistics"
    - Uber: Solves their biggest headache: *Uber Drivers*.
    - New Guy???... Faraday Future also ??? Others????

Discussion!

Thank You

alaink@princeton.edu

www.SmartDrivingCar.com

Very Likely…

- **ACA can reduce expected liability by 50% or more**

- **After 2 years, each of these systems would deliver ~ $3k to the bottom line.**

- **Plus numerous Disruptions, Injuries & Deaths are avoided for FREE.**

- **No substantive entity (Municipality, University, Corporation) should purchase a new vehicle that doesn't have 'Safe-driving' Technology**

2. Accelerate Deployment…

- **In somewhat restricted areas @ low speed**
  - **Retirement communities**

2. Accelerate Deployment...

- **In somewhat restricted areas @ low speed**
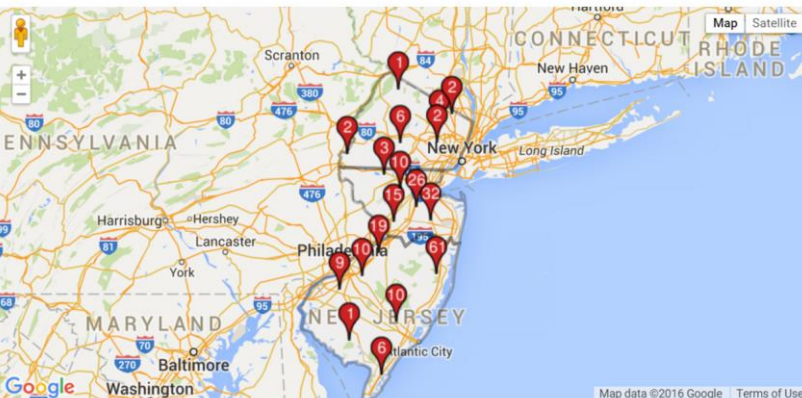 - **Retirement communities**
  - **Private campuses**

How can SmartDrivingCars Help Today?

- Substantially Reduce Crashes
  - Now Available… 'Safe-Driving' cars
- Provide Door2Door On-Demand Mobility in **55+ Gated Communities**
  - Now Available… Slow-Speed 'Driverless' Systems

New Jersey 55+ Active Adult Retirement Communities
Home > New Jersey

218 Communities in New Jersey

2. Accelerate Deployment…

- **In somewhat restricted areas @ low speed**
  - **Retirement communities**
  - **Private campuses**
  - **As alternatives to many proposed Light Rail Systems**
    - 'Purple Line'
    - 'Brooklyn' Light Rail
    - '42nd Street' Light Rail

2. Accelerate Deployment…

- **In somewhat restricted areas @ low speed**
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  - **As alternatives to many proposed Light Rail Systems**
    - **'Purple Line'**
    - **'Brooklyn' Light Rail**
    - **'42nd Street' Light Rail**
- **Why…**
  - **Good Mobility is Needed/Desired**
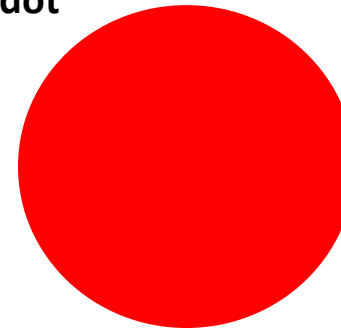   - **Low-speed driverless shuttles will provide better service, cheaper.**

Evolve to Deploy Fleets of Higher Speed autonomousTaxis of Various Sizes …

- **Why…Good mobility for everyone is Needed/Desired**
  - **We've looked at how such systems fleets could serve the mobility needs of New Jersey…**
  - **Could engender substantial Casual Ridesharing**
    - **Provide on-demand mobility to essentially everyone**
    - **Take today's AVO =~ 1.0 -> ~2.0**
      - **Cut Energy, Pollution, GHG in half!**
    - **Peak-hour, Peak direction AVO ~ 3.0**
      - **Eliminates congestion**
  - **Increase ridership on NJ Transit Rail by 5X**
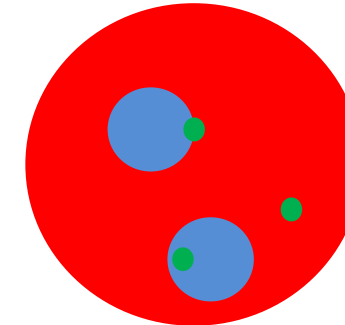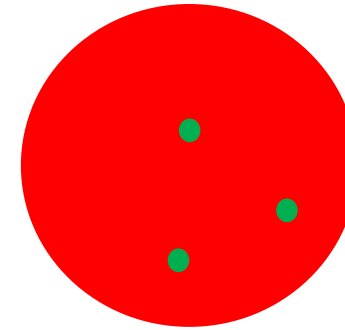   - **'Transit' would now serve 90% of the daily trips … Rule the World!**

Wait... 'Irrespective of the driver's discretion' ???

- **Cars** (or Trucks or Buses) **where, under some well-defined circumstances, each car can drive itself** (no human intervention)
  - **'Yesterday', ALL CIRCUMSTANCES required a licensed driver**
    - Let's represent these circumstances with a red dot

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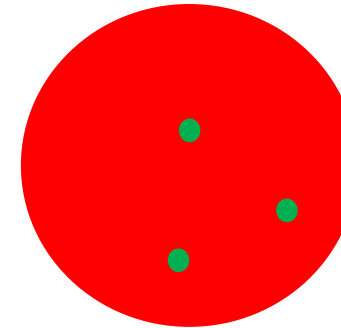   - Let's represent these circumstances with a **Green** dot

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The Center for Automated Road Transportation Safety

A Mobility Perspective on SmartDrivingCars:

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  (aka AutomatedCollisionAvoidance...)

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	12 mph test			25 mph test				Forward collision warning
Speed reduction (mph)	less than 5	5 to 9	10 or more	less than 5	5 to 9	10 to 21	22 or more	n/a
Points	0	1	2	0	1	2	3	1

From David Zuby's Presentation @ I-95 Corridor Coalition Connected & Automated Vehicles Conference, July 22, 2016

2005 Grand Challenge Team

Team Leader
Alain Kornhauser*71P03

Organizational Systems
Rachel Blair'06

Real-time Decision System
Andrew Saxe'08

Computing Systems
Anand Atreya'07

Mechanical Systems
Gordon Franken'08

Object Detection System
Brendan Collins'08
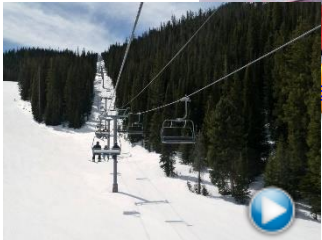
Electronic Systems
Bryan Cattle'07

Control Systems
Scott Schiffres'06

Planning Systems
Josh Herbach'08

Everyone Has Riden in a *Driverless* Vehicle

Tesla Car Transporter

Rio Tinto Automated Truck

Rio Tinto Automated Train

Tampa Airport 1st APM 1971

SkiLifts

Copenhagen Metro

Dusquene Incline

Milton Keynes, UK

Rivium 2006 ->

Elevator

CityMobil2

Heathrow PodCar

- **CAUTION**

  A **Driverless vehicle** has yet to 'drive' ***the 1ˢᵗ Foot*** without anyone in (or closely monitoring) the vehicle on a conventional, normally-operating public roadway!

  (a driverless vehicle has yet to drive **EMPTY** down 'Nassau Street in Princeton' or 'El Segundo Blvd in Mountainview' or the 'PA Turnpike' during Mid-day or even Mid-night!)

How can Smart Driving Cars Help?

- Provide Inexpensive Door2Door Mobility to all w/o Driver Privilege
  - Obviously enormous societal benefits; HOWEVER….
  - Requires "NHTSA Level4" Driverless "autonomousTaxi"
    - Else it must incur a labor cost
  - Bad News….Unlikely Soon…
    - California Proposed Regulations Forbid Testing of "Driverless" on Public Streets
    - We have yet to go the "first meter" Driverless on an "unprepared" Public Street
  - Good News…. Experience with the near-term "Level2" & "slow-speed Level 4" will prepare us to achieve the general "NHTSA Level4" Driverless aTaxi"

What are the Bottlenecks in Trans-Hudson Mobility

- Automobiles
  - Forget about it
- Rail
  - The Amtrak Tunnels
  - Few stations
- Buses
  - PABT
  - 495 viaduct
  - Lincoln Tunnel

Increasing Bus Capacity To Mid-town Manhattan Would Involve Three Elements:
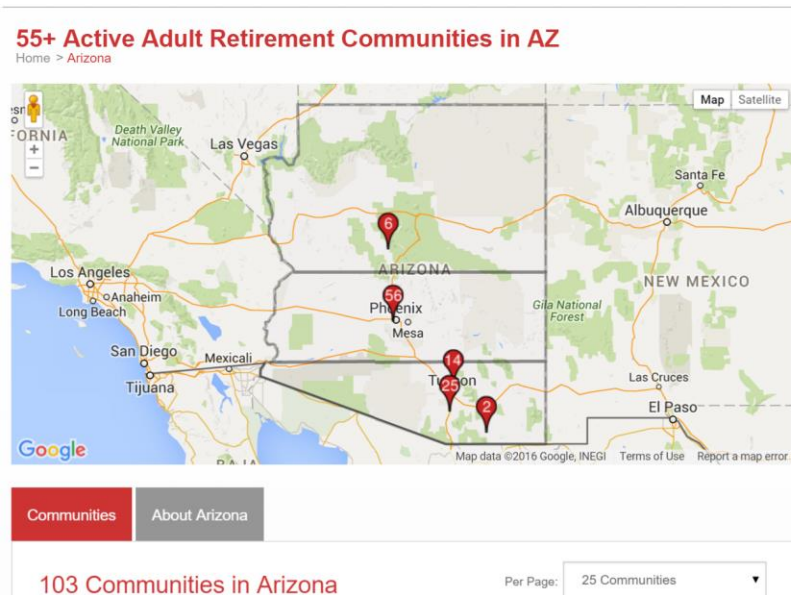
- Increasing the capacity of the PABT, particularly to accommodate outbound passengers in the PM peak*

- Increasing the capacity to feed buses into the terminal for PM outbound service, either by making bus storage space available in Manhattan or by expediting the PM eastbound flow of buses through the Lincoln Tunnel.

- Increasing the AM peak hour flow of buses through the XBL

        *currently under study

How can Smart Driving Cars Help?

- Substantially Reduce Accidents of Elderly still driving

  - Now Available… "NHTSA Level2" ADAS (Automated Driver Assistance Systems)

- Provide Door2Door On-Demand Mobility in **55+ Gated Communities**

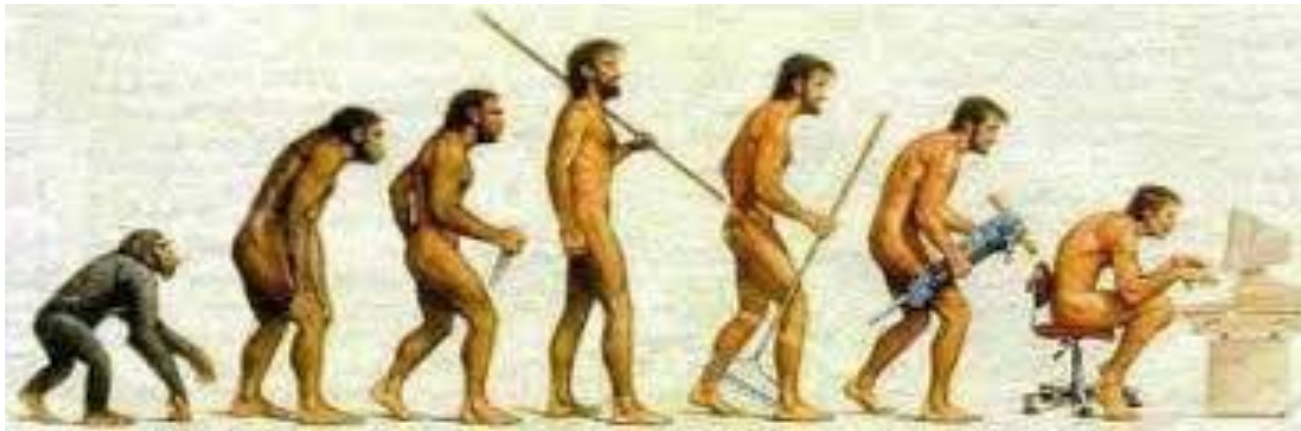 – Now Available… "Slow-Speed, NHTSA Level4" Driverless Systems

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- Provide Door2Door On-Demand Mobility in **55+ Gated Communities**

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Pennsylvania 55+ Active Adult Retirement Communities
Home > Pennsylvania

129 Communities in Pennsylvania

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0 "55 Chevy"	Many Accidents, High Claims	Freedom Life Style	Market Dominance (Madison Avenue)	Death trap
0+ "Crash Mitigation" (air bags, seat belts, energy absorbing)	Many Accidents, Higher Claims	Disdain	Public sector; Law enforcement	Fewer deaths
0+ "0th generation automated systems" : (Anti-lock Brakes & Electronic Stability Control)	less # claims; but $$$ higher	Some Comfort	Public sector	Slightly fewer crashes
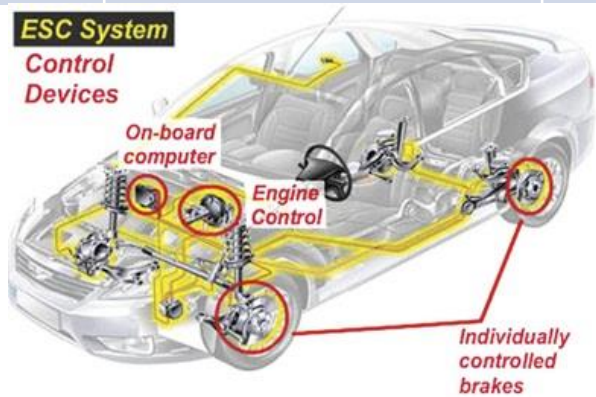
Both: Override the driver and "Do the right thing"

Prospect Eleven & 2005 Competition

the making of a monster

2005 Grand Challenge

2005 Grand Challenge Team

Team Leader
Alain Kornhauser*71P03

Real-time Decision System
Andrew Saxe'08

Organizational Systems
Rachel Blair'06

Computing Systems
Anand Atreya'07

Mechanical Systems
Gordon Franken'08

Object Detection System
Brendan Collins'08

Electronic Systems
Bryan Cattle'07

Control Systems
Scott Schiffres'06

Planning Systems
Josh Herbach'08

Objective

- Enrich the academic experience of the students

Constraints

- Very little budget

Guiding Principles

- Simplicity

Homemade

"Unlike the fancy "drive by wire" system employed by Stanford and VW, Princeton's students built a homemade set of gears to drive their pickup. I could see from the electronics textbook they were using that they were learning as they went."

http://www.pcmag.com/slideshow_viewer/0,1205,l=&s=1489&a=161569&po=2,00.asp

Fall 2004

Fall 2005

It wasn't so easy…

It Wasn't So Easy

Pimp My Ride

[Link to GPS Tracks](#)